INPUT SET 1: User defined Matrix in binary depicting an image.

Standard C++ (with fetch)

S no	Width	Height	Pixels	Edge	Erosion	Dilation	Opening	Closing
1	50	25	1250	0.015	0.016	0.031	0.015	0.015
2	50	50	2500	0.063	0.047	0.078	0.047	0.047
3	50	75	3750	0.078	0.093	0.125	0.094	0.094
4	50	100	5000	0.062	0.079	0.11	0.062	0.078
5	50	125	6250	0.078	0.062	0.109	0.078	0.078
6	50	150	7500	0.11	0.109	0.156	0.11	0.11
7	50	300	15000	0.281	0.282	0.406	0.281	0.281
8	50	450	22500	0.297	0.281	0.547	0.297	0.297
9	50	600	30000	0.67	0.625	0.95	0.625	0.641
10	50	1200	60000	0.859	0.875	2.324	2.299	2.39
11	50	1800	90000	1.625	1.717	1.799	1.422	1.829
12	50	2400	120000	1.719	1.578	1.688	2.047	1.907
13	50	3000	150000	2.221	2.282	2.719	2.403	2.453
14	50	6000	300000	4.779	4.189	4.499	4.081	4.156
15	50	9000	450000	6.033	6.295	6.576	6.357	6.108
16	50	12000	600000	8.594	8.328	8.549	8.656	8.524
17	50	15000	750000	10.482	10.61	10.58	10.719	10.725
18	50	18000	900000	13.314	12.828	12.621	11.987	13.19
19	50	36000	1800000	27.143	26.841	25.345	25.498	26.825
20	50	54000	2700000	38.858	38.471	38.376	38.282	38.951
			Total Time:	**117.281**	**115.608**	**117.588**	**115.36**	**118.699**
			Average	5.86405	5.7804	5.8794	5.768	5.93495

CUDA C (with fetch)

S no	Width	Height	Pixels	Edge	Erosion	Dilation	Opening	Closing
1	50	25	1250	1.088	1.735	2.04	1.139	1.907
2	50	50	2500	0.344	0.047	0.084	0.031	0.031
3	50	75	3750	0.047	0.047	0.126	0.031	0.047
4	50	100	5000	0.062	0.062	0.118	0.078	0.062
5	50	125	6250	0.063	0.078	0.125	0.078	0.063
6	50	150	7500	0.093	0.099	0.112	0.094	0.094
7	50	300	15000	0.157	0.166	0.277	0.156	0.156
8	50	450	22500	0.25	0.233	0.368	0.234	0.25
9	50	600	30000	0.328	0.328	0.421	0.344	0.328
10	50	1200	60000	1.453	0.657	0.664	0.665	0.672
11	50	1800	90000	1.404	1.031	0.73	0.999	1
12	50	2400	120000	1.704	1.297	0.926	1.324	1.312
13	50	3000	150000	1.641	1.643	0.906	1.64	1.642
14	50	6000	300000	4.672	3.297	2.266	3.279	3.305
15	50	9000	450000	5.625	5.169	5.328	4.924	4.925
16	50	12000	600000	8.296	6.674	6.734	6.608	6.487
17	50	15000	750000	9.893	8.373	8.362	7.86	8.266
18	50	18000	900000	12.626	10.19	10.112	9.36	9.921
19	50	36000	1800000	25.229	20.7	21.161	21.039	20.257
20	50	54000	2700000	37.127	29.427	30.211	31.384	29.632
			Total Time:	**112.102**	**91.253**	**91.071**	**91.267**	**90.357**
			Average	5.6051	4.56265	4.55355	4.56335	4.51785

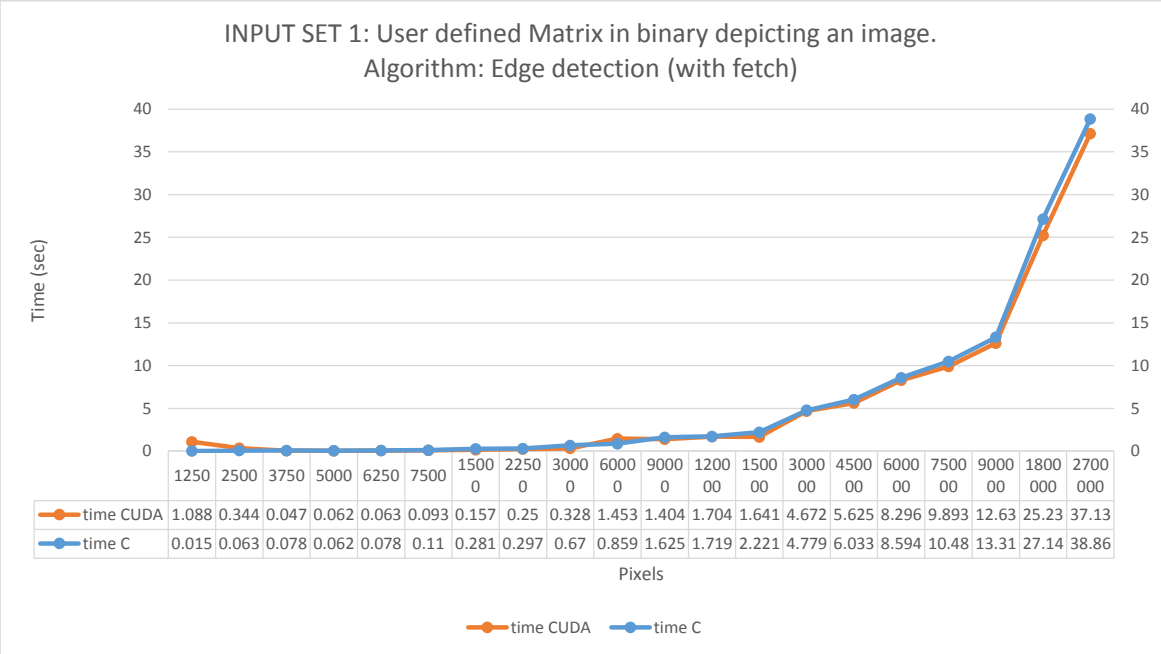
INPUT SET 1: User defined Matrix in binary depicting an image.

Standard C++ (without fetch)

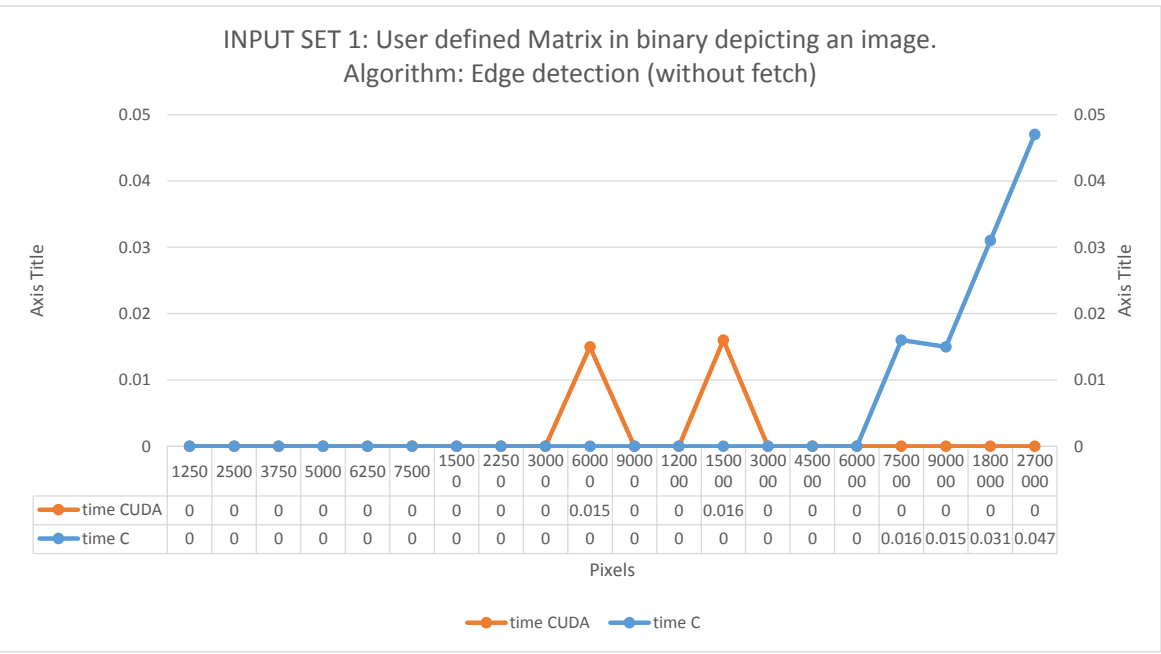
S no	Width	Height	Pixels	Edge	Erosion	Dilation	Opening	Closing
1	50	25	1250	0	0	0	0	0
2	50	50	2500	0	0	0	0	0
3	50	75	3750	0	0	0	0	0.016
4	50	100	5000	0	0.016	0	0	0.015
5	50	125	6250	0	0	0	0	0
6	50	150	7500	0	0	0	0	0
7	50	300	15000	0	0.016	0	0.016	0
8	50	450	22500	0	0	0.015	0.015	0
9	50	600	30000	0	0.015	0	0.015	0
10	50	1200	60000	0	0.015	0	0.032	0.008
11	50	1800	90000	0	0.015	0.016	0.032	0.031
12	50	2400	120000	0	0.031	0.031	0.047	0.047
13	50	3000	150000	0	0.031	0.032	0.047	0.062
14	50	6000	300000	0	0.047	0.047	0.125	0.11
15	50	9000	450000	0	0.093	0.093	0.156	0.171
16	50	12000	600000	0	0.11	0.109	0.219	0.222
17	50	15000	750000	0.016	0.141	0.141	0.282	0.312
18	50	18000	900000	0.015	0.234	0.156	0.328	0.329
19	50	36000	1800000	0.031	0.344	0.328	0.657	0.651
20	50	54000	2700000	0.047	0.5	0.5	0.922	0.985
			Total Time:	**0.109**	**1.608**	**1.468**	**2.893**	**2.959**
			Average	0.00545	0.0804	0.0734	0.14465	0.14795

CUDA C (without fetch)

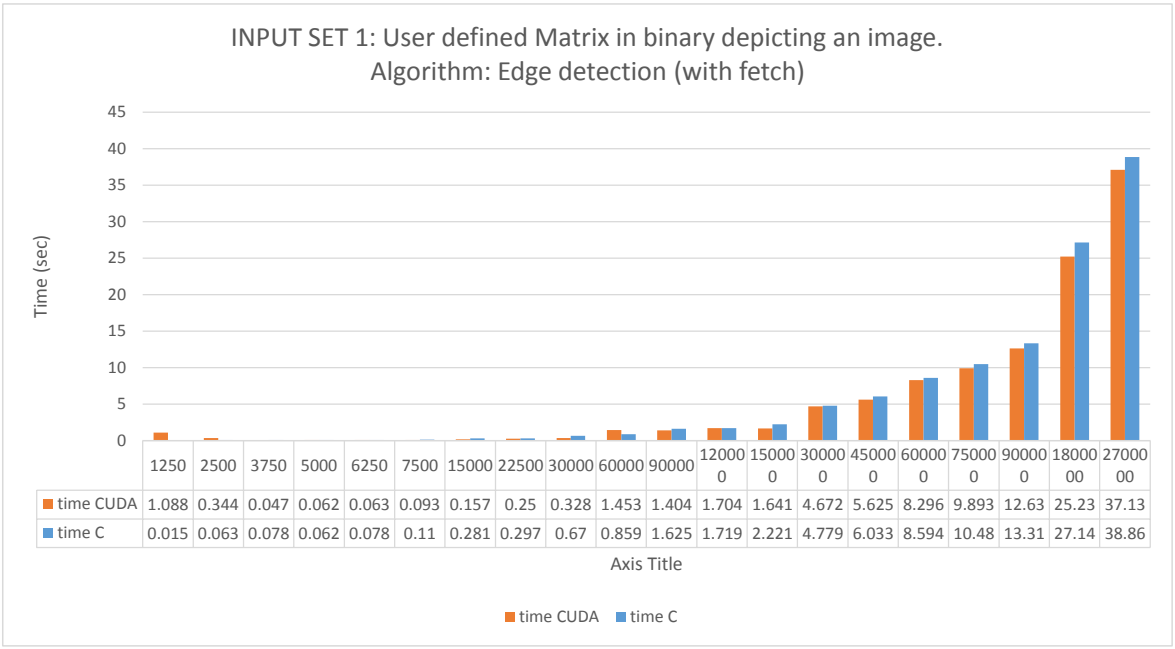
S no	Width	Height	Pixels	Edge	Erosion	Dilation	Opening	Closing
1	50	25	1250	0	0	0.001	0	0
2	50	50	2500	0	0	0.001	0	0
3	50	75	3750	0	0	0.001	0	0
4	50	100	5000	0	0	0	0	0
5	50	125	6250	0	0	0	0	0
6	50	150	7500	0	0	0	0	0
7	50	300	15000	0	0.001	0.001	0	0
8	50	450	22500	0	0	0.001	0	0
9	50	600	30000	0	0	0.001	0	0
10	50	1200	60000	0.015	0	0.001	0	0
11	50	1800	90000	0	0	0	0	0
12	50	2400	120000	0	0	0	0	0
13	50	3000	150000	0.016	0	0	0	0
14	50	6000	300000	0	0	0	0	0.001
15	50	9000	450000	0	0	0.016	0	0.002
16	50	12000	600000	0	0.016	0	0	0
17	50	15000	750000	0	0	0	0	0
18	50	18000	900000	0	0	0	0	0
19	50	36000	1800000	0	0.016	0.001	0.002	0.001
20	50	54000	2700000	0	0.001	0	0	0
			Total Time:	**0.031**	**0.034**	**0.024**	**0.002**	**0.004**
			Average	0.00155	0.0017	0.0012	0.0001	0.0002



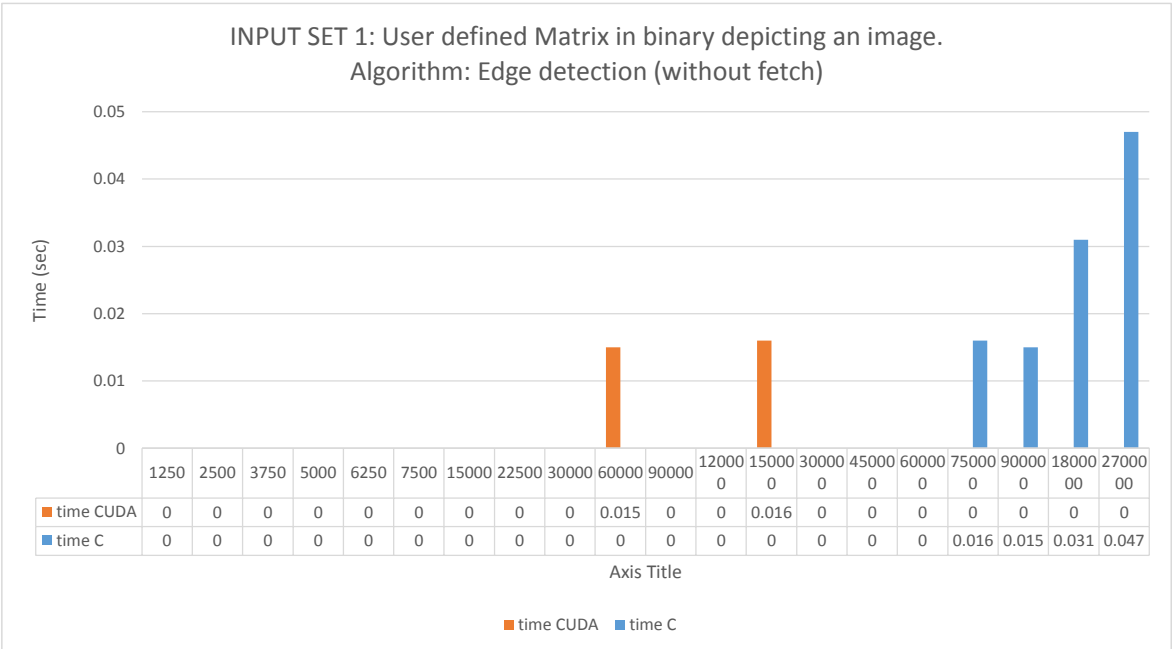
	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	1.088	0.344	0.047	0.062	0.063	0.093	0.157	0.25	0.328	1.453	1.404	1.704	1.641	4.672	5.625	8.296	9.893	12.63	25.23	37.13
time C	0.015	0.063	0.078	0.062	0.078	0.11	0.281	0.297	0.67	0.859	1.625	1.719	2.221	4.779	6.033	8.594	10.48	13.31	27.14	38.86



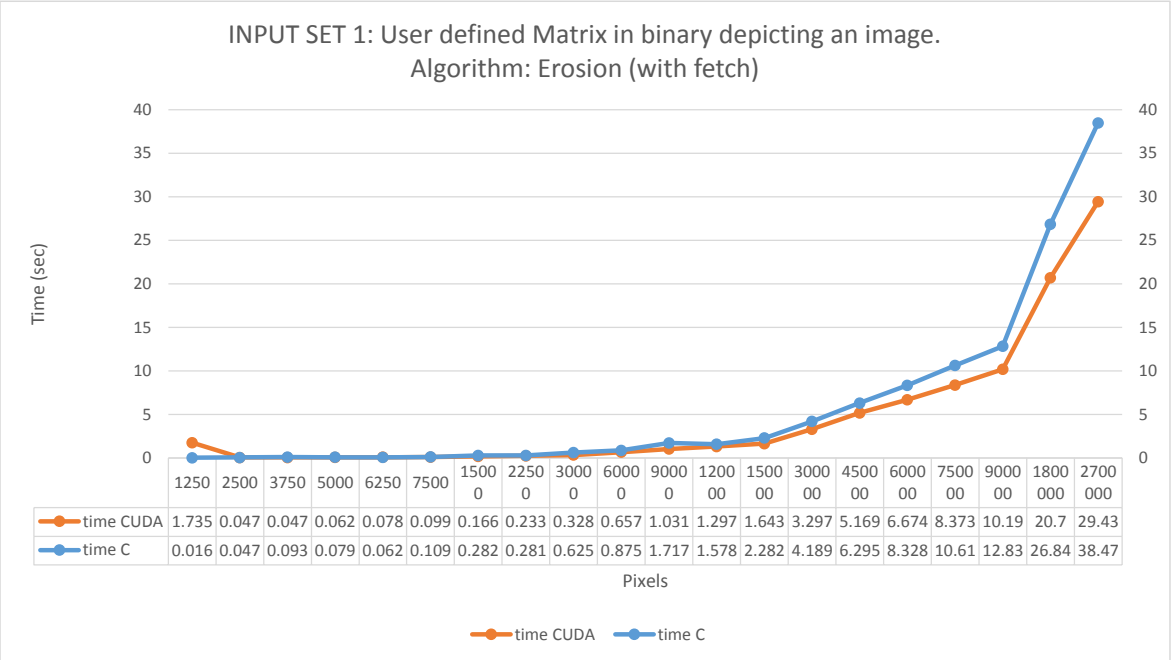
	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	0	0	0	0	0	0	0	0	0	0.015	0	0	0.016	0	0	0	0	0	0	0
time C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.016	0.015	0.031	0.047



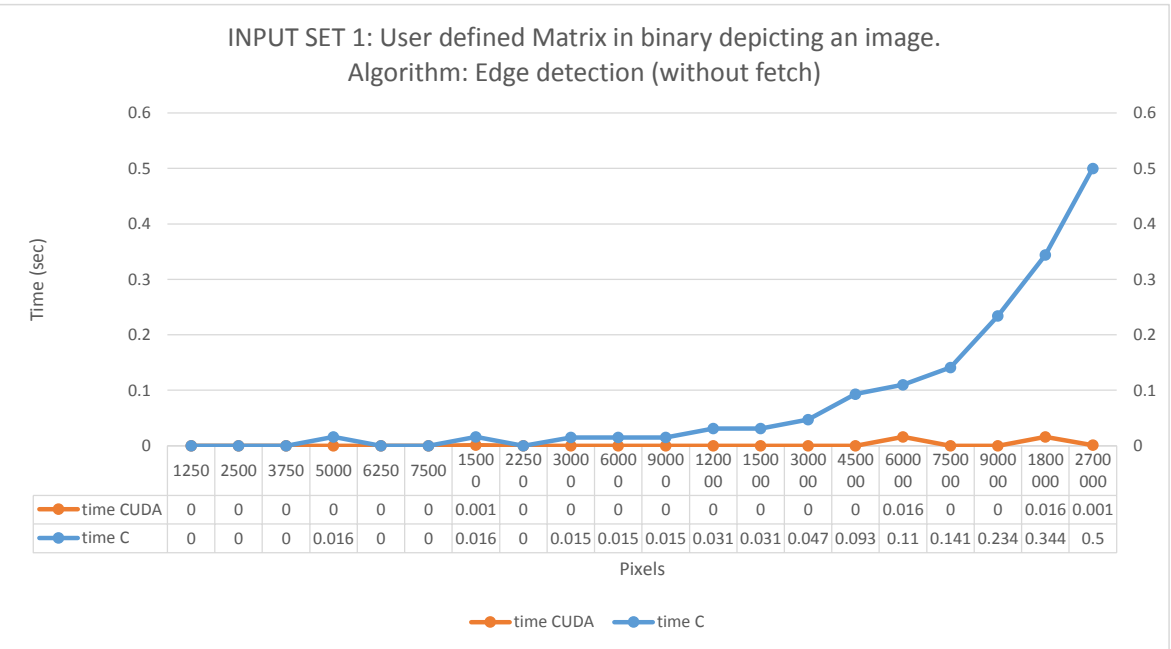
	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	1.088	0.344	0.047	0.062	0.063	0.093	0.157	0.25	0.328	1.453	1.404	1.704	1.641	4.672	5.625	8.296	9.893	12.63	25.23	37.13
time C	0.015	0.063	0.078	0.062	0.078	0.11	0.281	0.297	0.67	0.859	1.625	1.719	2.221	4.779	6.033	8.594	10.48	13.31	27.14	38.86



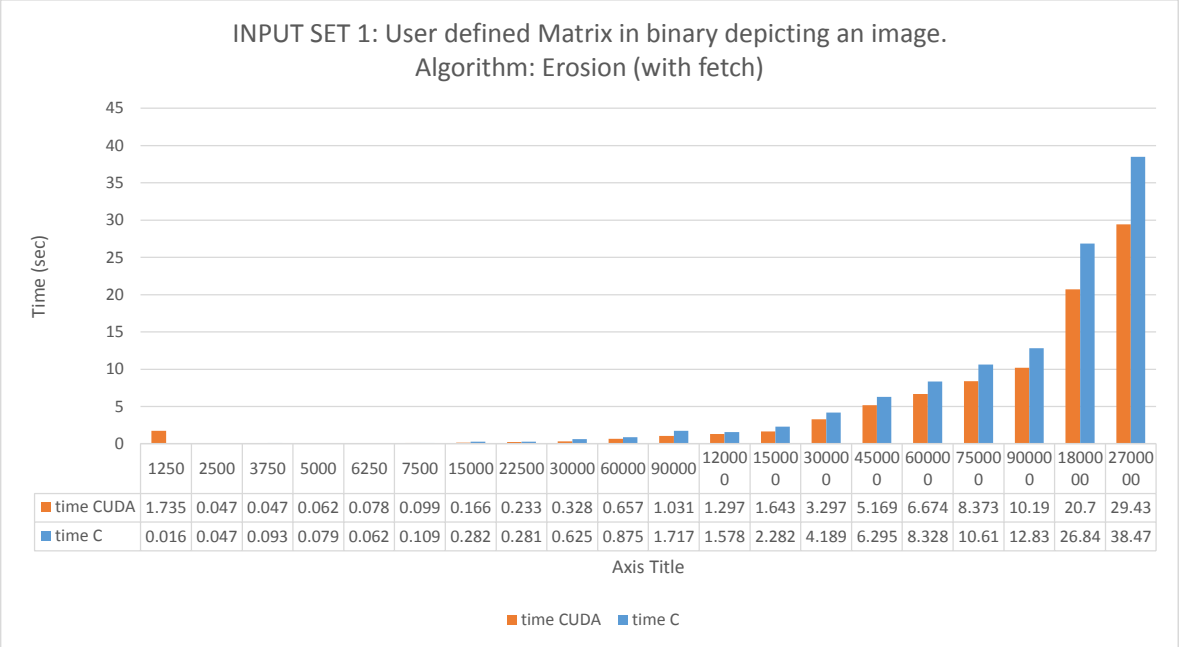
	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	0	0	0	0	0	0	0	0	0	0.015	0	0	0.016	0	0	0	0	0	0	0
time C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.016	0.015	0.031	0.047



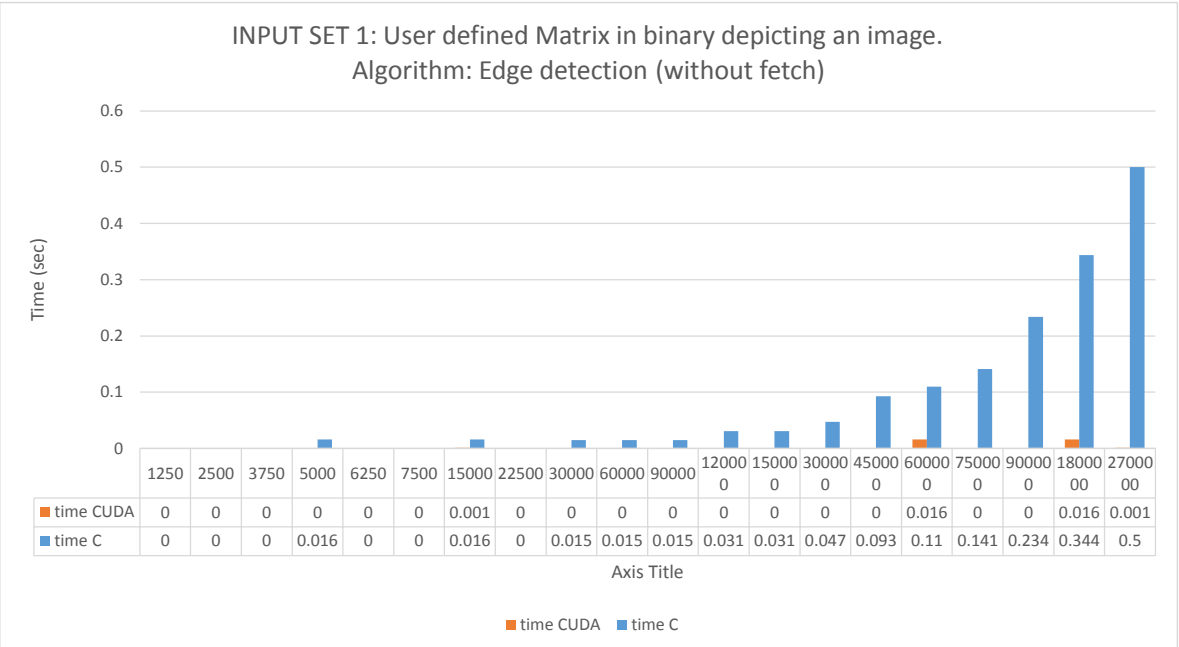
	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	1.735	0.047	0.047	0.062	0.078	0.099	0.166	0.233	0.328	0.657	1.031	1.297	1.643	3.297	5.169	6.674	8.373	10.19	20.7	29.43
time C	0.016	0.047	0.093	0.079	0.062	0.109	0.282	0.281	0.625	0.875	1.717	1.578	2.282	4.189	6.295	8.328	10.61	12.83	26.84	38.47



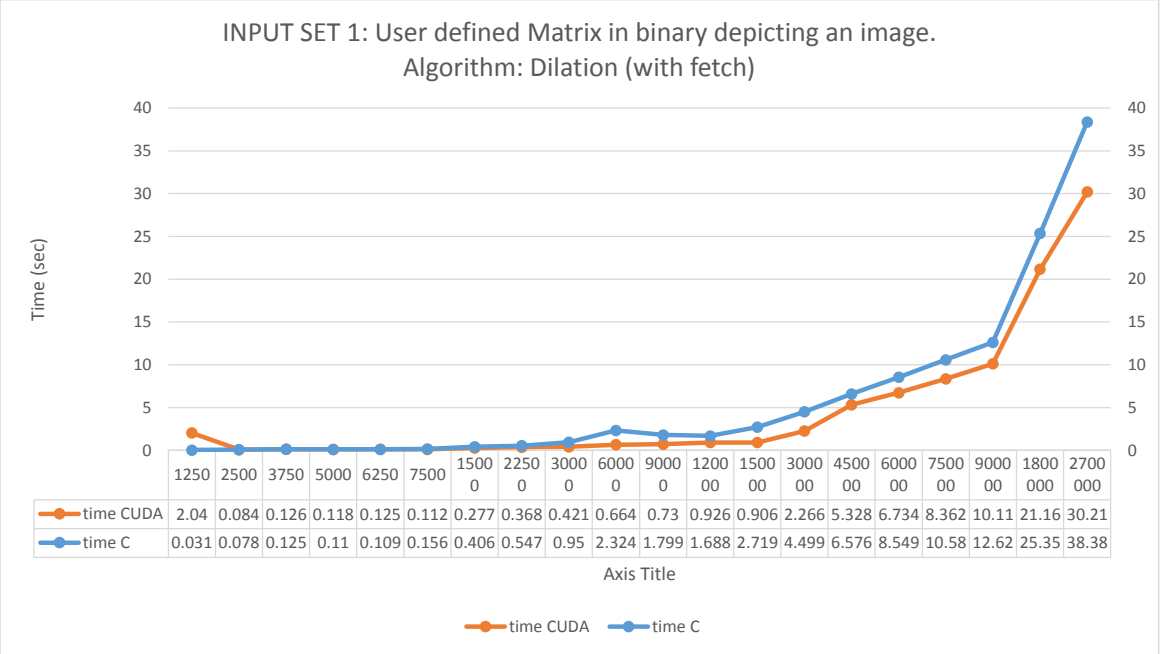
	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	0	0	0	0	0	0	0.001	0	0	0	0	0	0	0	0	0.016	0	0	0.016	0.001
time C	0	0	0	0.016	0	0	0.016	0	0.015	0.015	0.015	0.031	0.031	0.047	0.093	0.11	0.141	0.234	0.344	0.5



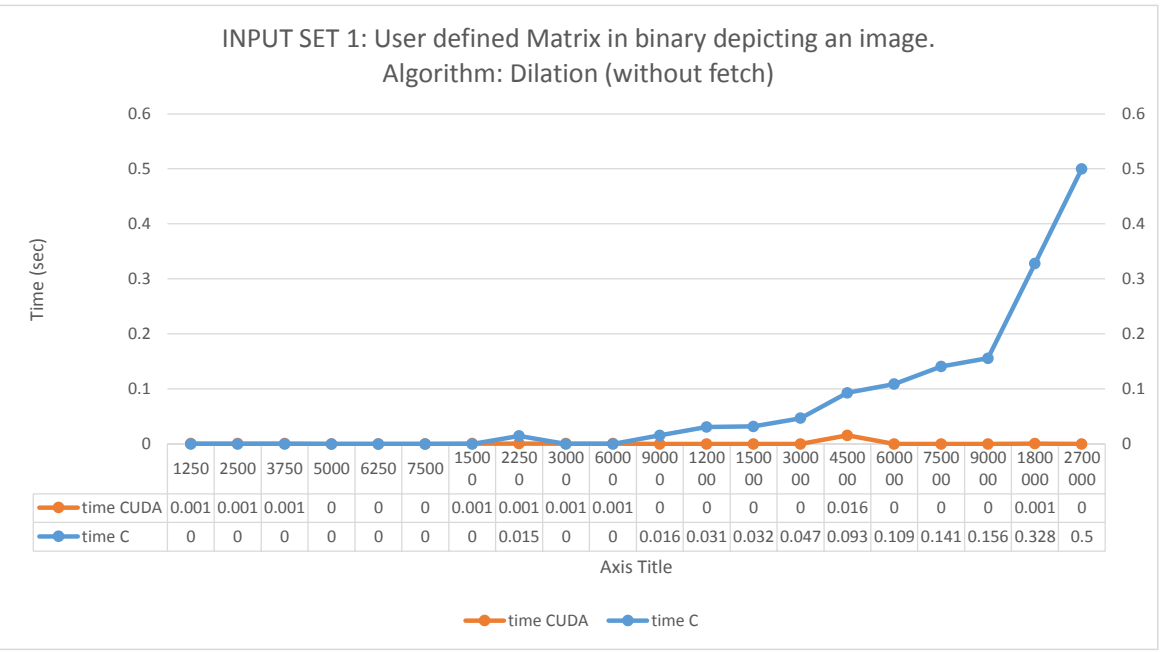
	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	1.735	0.047	0.047	0.062	0.078	0.099	0.166	0.233	0.328	0.657	1.031	1.297	1.643	3.297	5.169	6.674	8.373	10.19	20.7	29.43
time C	0.016	0.047	0.093	0.079	0.062	0.109	0.282	0.281	0.625	0.875	1.717	1.578	2.282	4.189	6.295	8.328	10.61	12.83	26.84	38.47



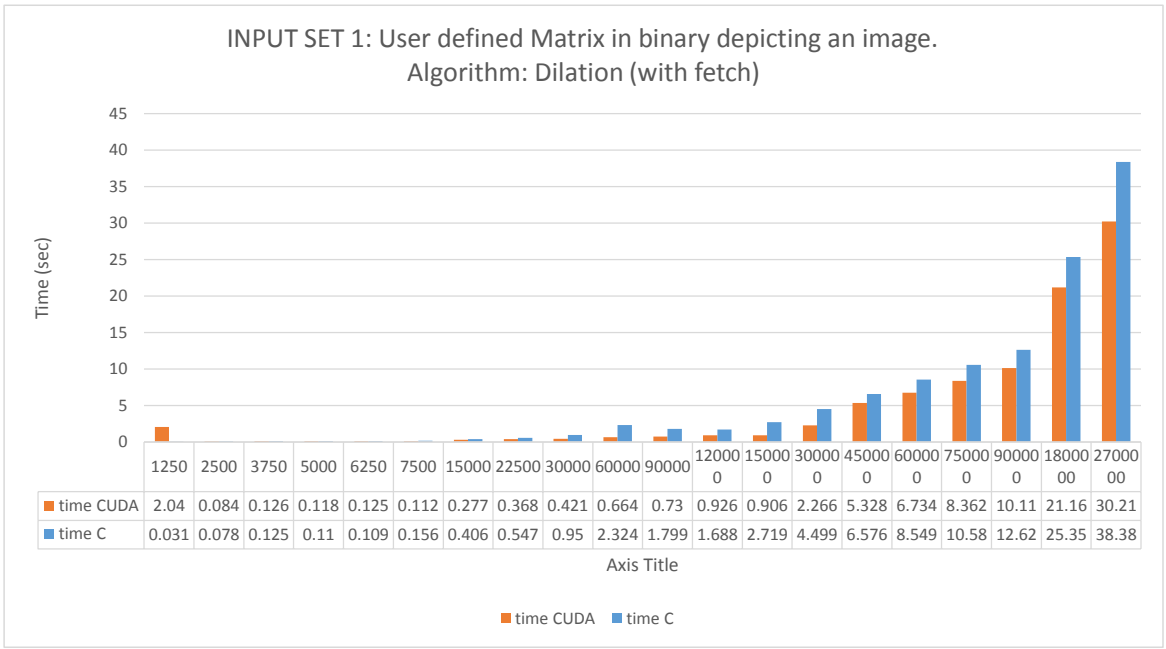
	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	0	0	0	0	0	0	0.001	0	0	0	0	0	0	0	0	0.016	0	0	0.016	0.001
time C	0	0	0	0.016	0	0	0.016	0	0.015	0.015	0.015	0.031	0.031	0.047	0.093	0.11	0.141	0.234	0.344	0.5



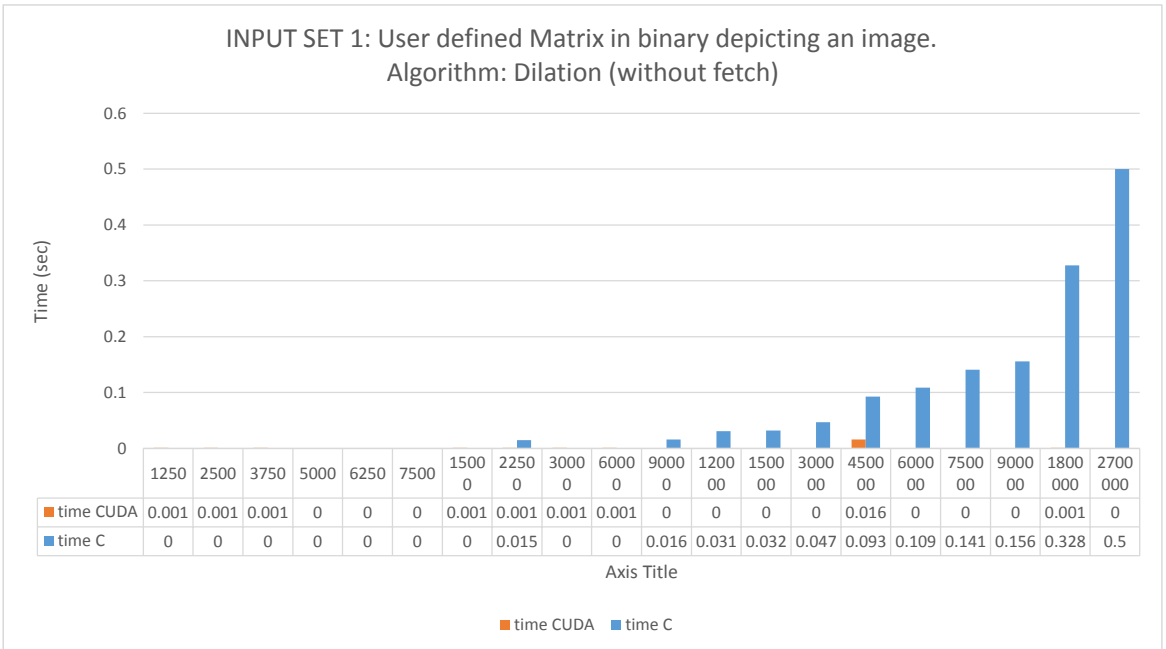
	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	2.04	0.084	0.126	0.118	0.125	0.112	0.277	0.368	0.421	0.664	0.73	0.926	0.906	2.266	5.328	6.734	8.362	10.11	21.16	30.21
time C	0.031	0.078	0.125	0.11	0.109	0.156	0.406	0.547	0.95	2.324	1.799	1.688	2.719	4.499	6.576	8.549	10.58	12.62	25.35	38.38



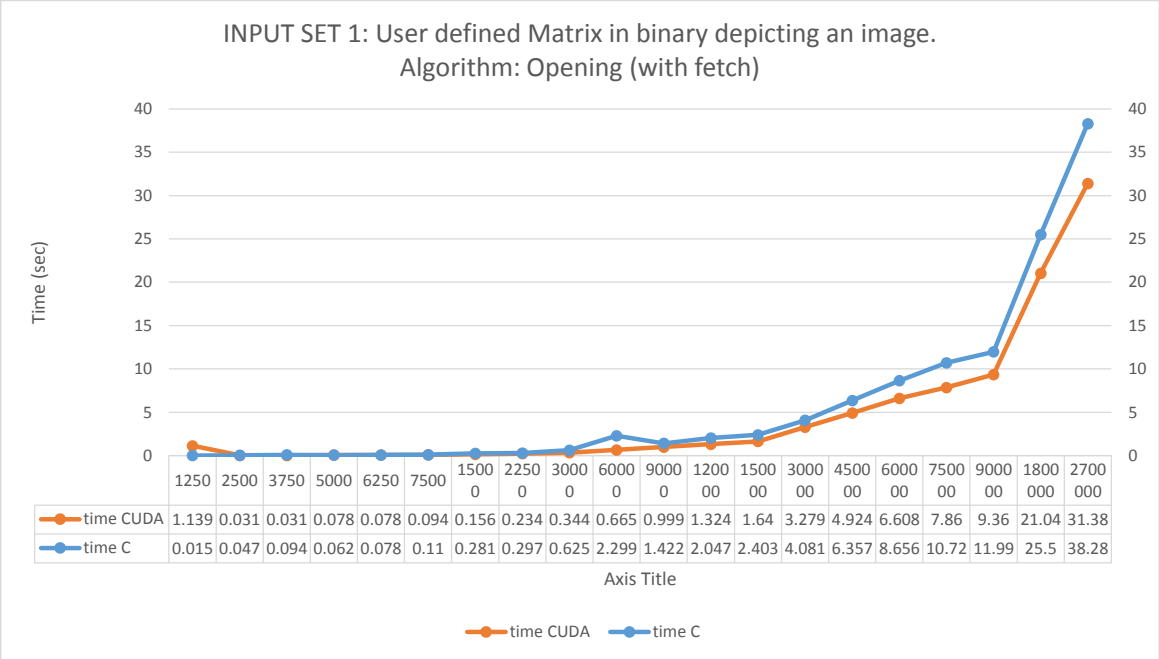
	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	0.001	0.001	0.001	0	0	0	0.001	0.001	0.001	0.001	0	0	0	0	0.016	0	0	0	0.001	0
time C	0	0	0	0	0	0	0	0.015	0	0	0.016	0.031	0.032	0.047	0.093	0.109	0.141	0.156	0.328	0.5



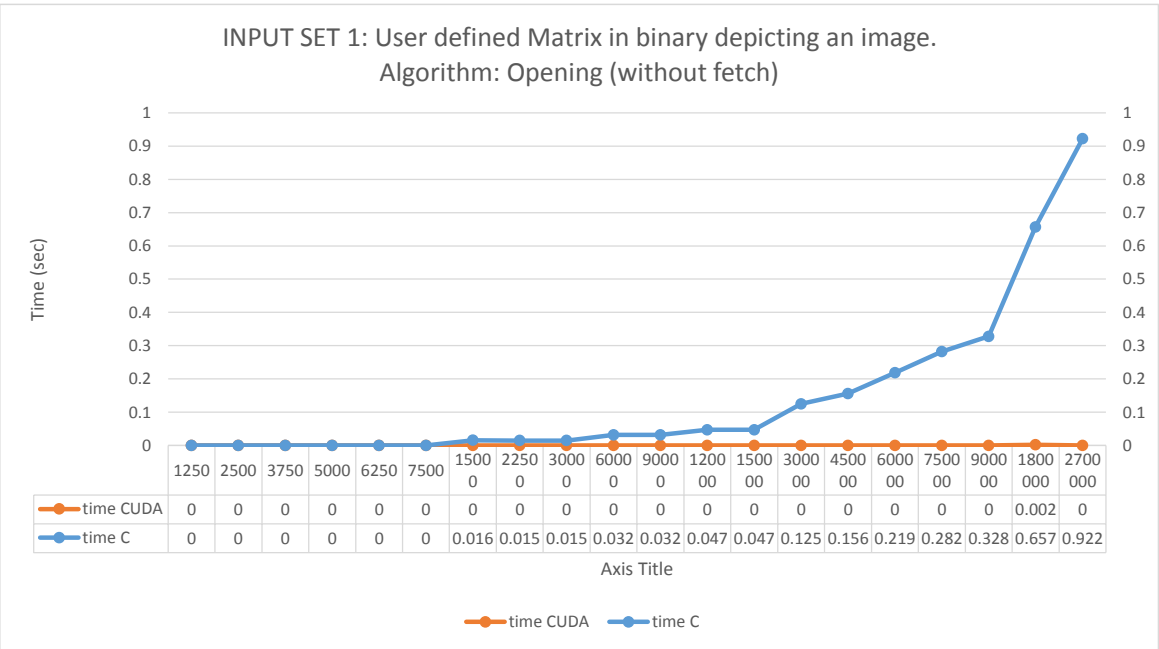
	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	2.04	0.084	0.126	0.118	0.125	0.112	0.277	0.368	0.421	0.664	0.73	0.926	0.906	2.266	5.328	6.734	8.362	10.11	21.16	30.21
time C	0.031	0.078	0.125	0.11	0.109	0.156	0.406	0.547	0.95	2.324	1.799	1.688	2.719	4.499	6.576	8.549	10.58	12.62	25.35	38.38



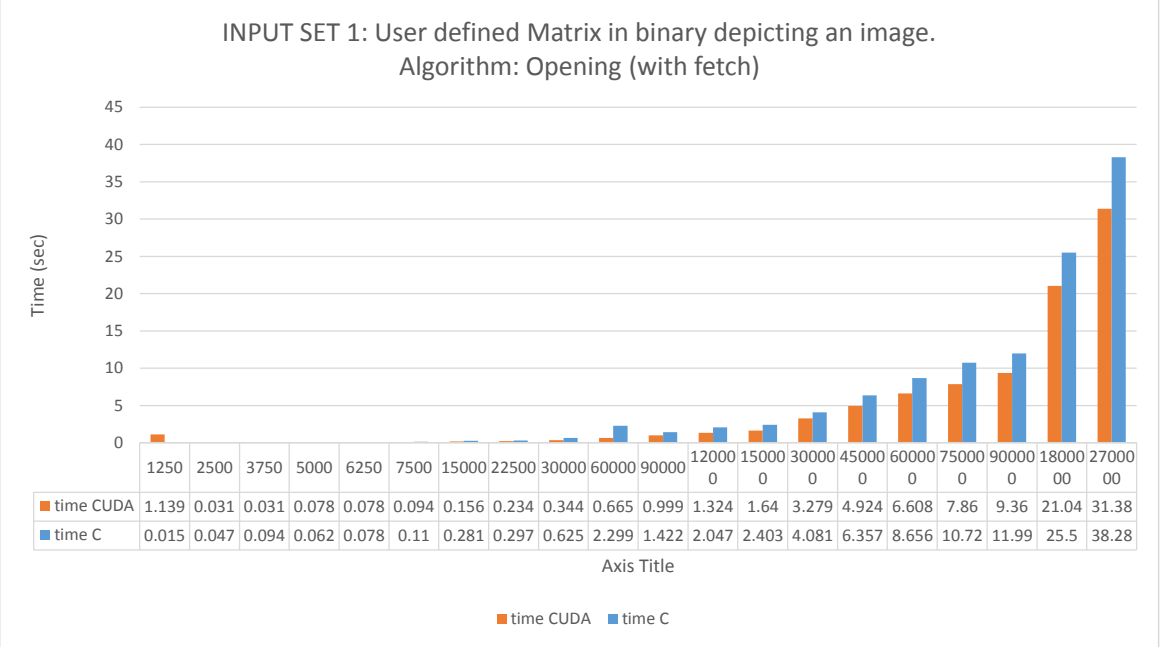
	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	0.001	0.001	0.001	0	0	0	0.001	0.001	0.001	0.001	0	0	0	0	0.016	0	0	0	0.001	0
time C	0	0	0	0	0	0	0	0.015	0	0	0.016	0.031	0.032	0.047	0.093	0.109	0.141	0.156	0.328	0.5

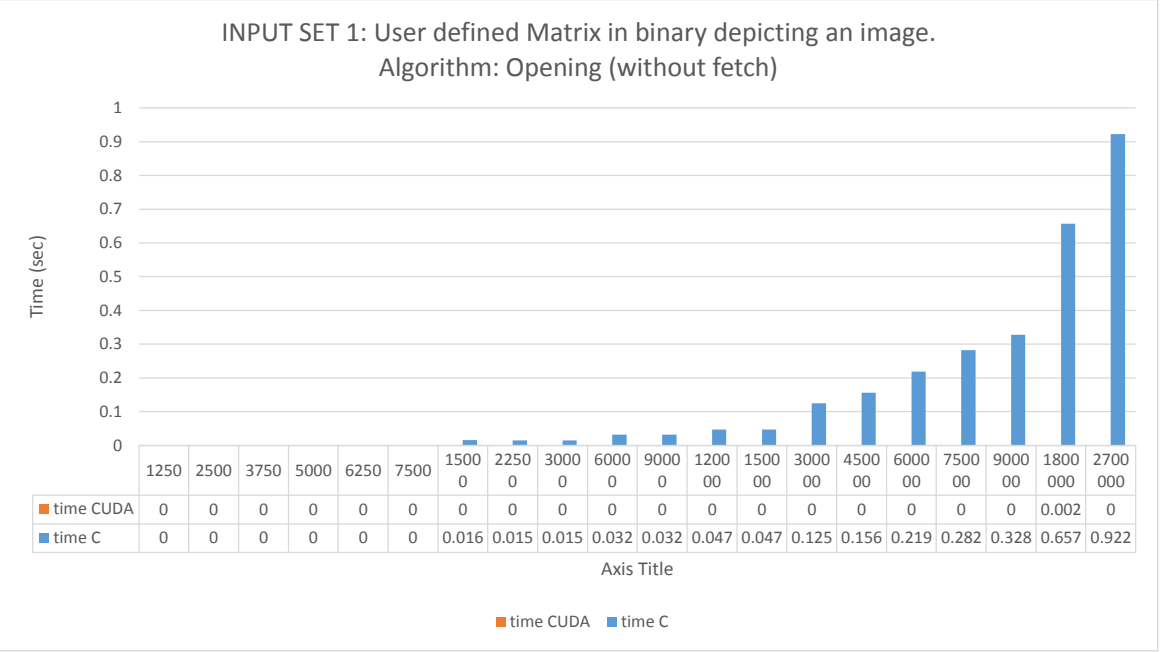


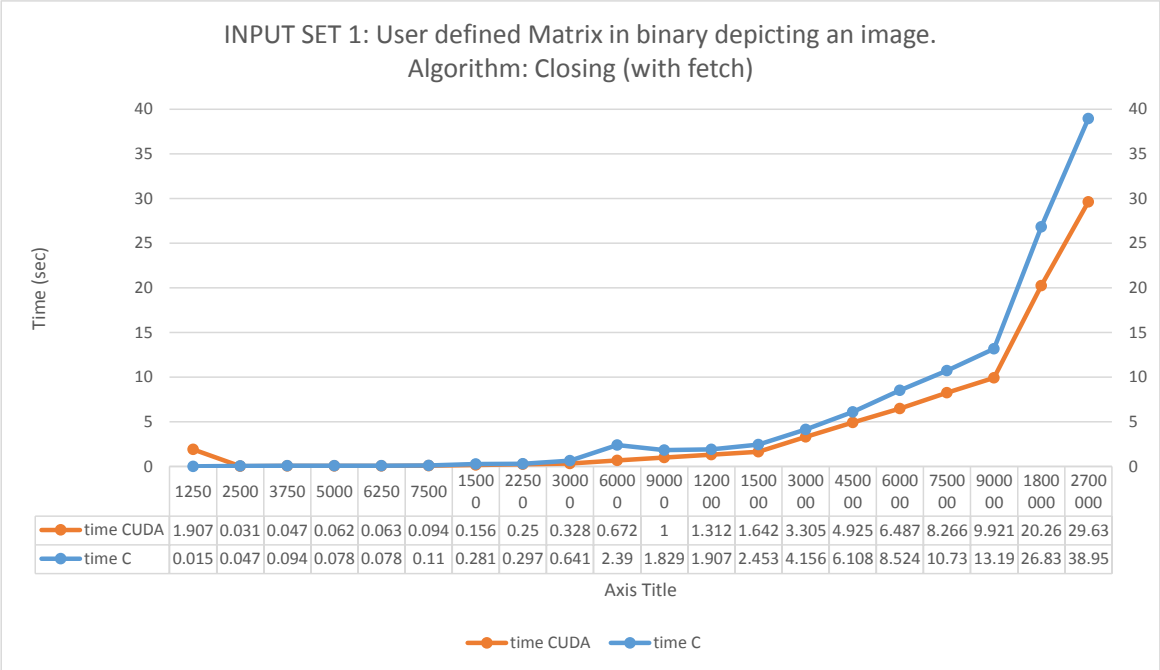
	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	1.139	0.031	0.031	0.078	0.078	0.094	0.156	0.234	0.344	0.665	0.999	1.324	1.64	3.279	4.924	6.608	7.86	9.36	21.04	31.38
time C	0.015	0.047	0.094	0.062	0.078	0.11	0.281	0.297	0.625	2.299	1.422	2.047	2.403	4.081	6.357	8.656	10.72	11.99	25.5	38.28



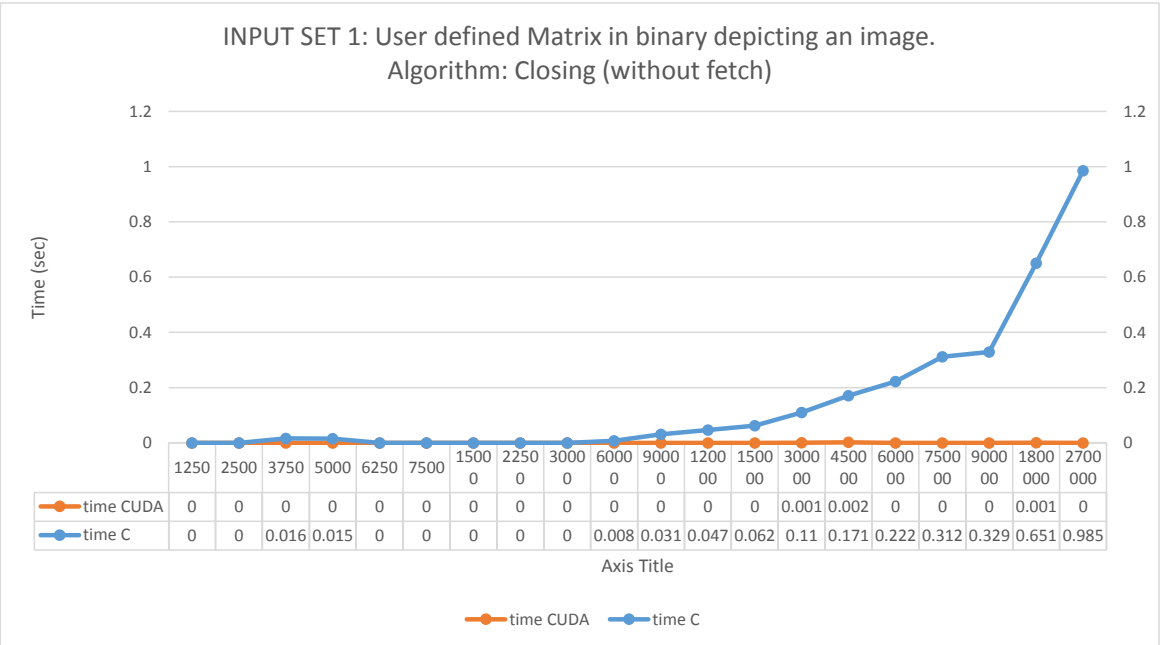
	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.002	0
time C	0	0	0	0	0	0	0.016	0.015	0.015	0.032	0.032	0.047	0.047	0.125	0.156	0.219	0.282	0.328	0.657	0.922


INPUT SET 1: User defined Matrix in binary depicting an image.
Algorithm: Opening (with fetch)
Time (sec)
45
40
35
30
25
20
15
10
5
0
1250 2500 3750 5000 6250 7500 15000 22500 30000 60000 90000 120000 150000 300000 450000 600000 750000 900000 1800000 2700000
time CUDA 1.139 0.031 0.031 0.078 0.078 0.094 0.156 0.234 0.344 0.665 0.999 1.324 1.64 3.279 4.924 6.608 7.86 9.36 21.04 31.38
time C 0.015 0.047 0.094 0.062 0.078 0.11 0.281 0.297 0.625 2.299 1.422 2.047 2.403 4.081 6.357 8.656 10.72 11.99 25.5 38.28
Axis Title
time CUDA
time C

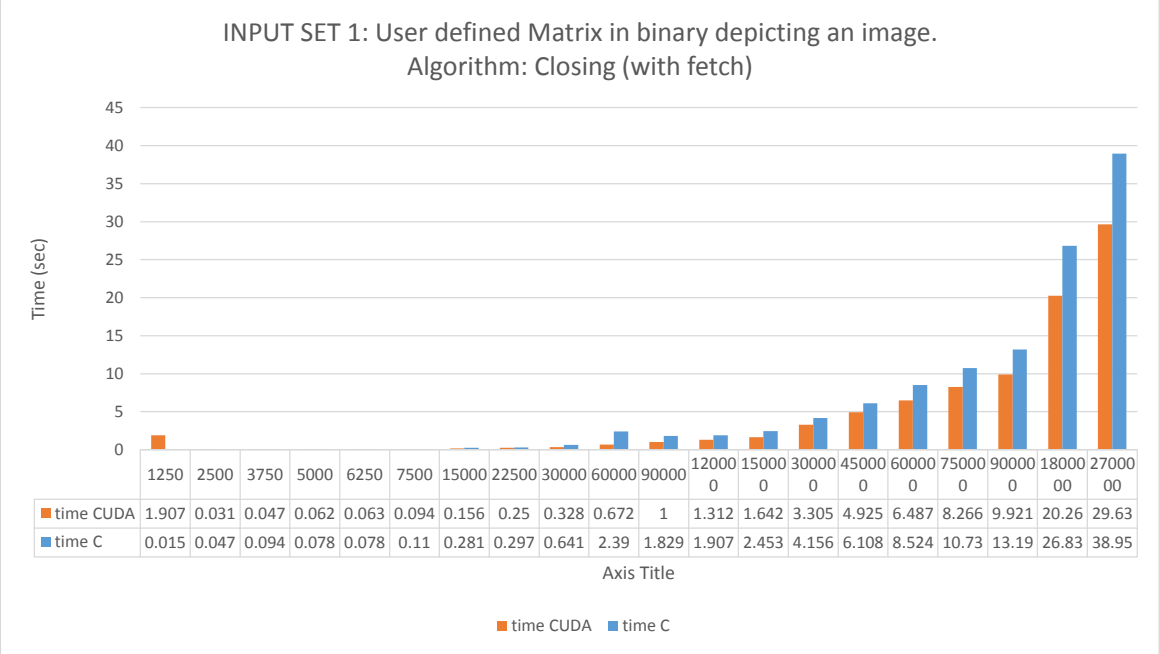

INPUT SET 1: User defined Matrix in binary depicting an image.
Algorithm: Opening (without fetch)
Time (sec)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1250 2500 3750 5000 6250 7500 15000 22500 30000 60000 90000 120000 150000 300000 450000 600000 750000 900000 1800000 2700000
time CUDA 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0.002 0
time C 0 0 0 0 0 0 0.016 0.015 0.015 0.032 0.032 0.047 0.047 0.125 0.156 0.219 0.282 0.328 0.657 0.922
Axis Title
time CUDA
time C



	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	1.907	0.031	0.047	0.062	0.063	0.094	0.156	0.25	0.328	0.672	1	1.312	1.642	3.305	4.925	6.487	8.266	9.921	20.26	29.63
time C	0.015	0.047	0.094	0.078	0.078	0.11	0.281	0.297	0.641	2.39	1.829	1.907	2.453	4.156	6.108	8.524	10.73	13.19	26.83	38.95



	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0.002	0	0	0	0.001	0
time C	0	0	0.016	0.015	0	0	0	0	0	0.008	0.031	0.047	0.062	0.11	0.171	0.222	0.312	0.329	0.651	0.985



	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	1.907	0.031	0.047	0.062	0.063	0.094	0.156	0.25	0.328	0.672	1	1.312	1.642	3.305	4.925	6.487	8.266	9.921	20.26	29.63
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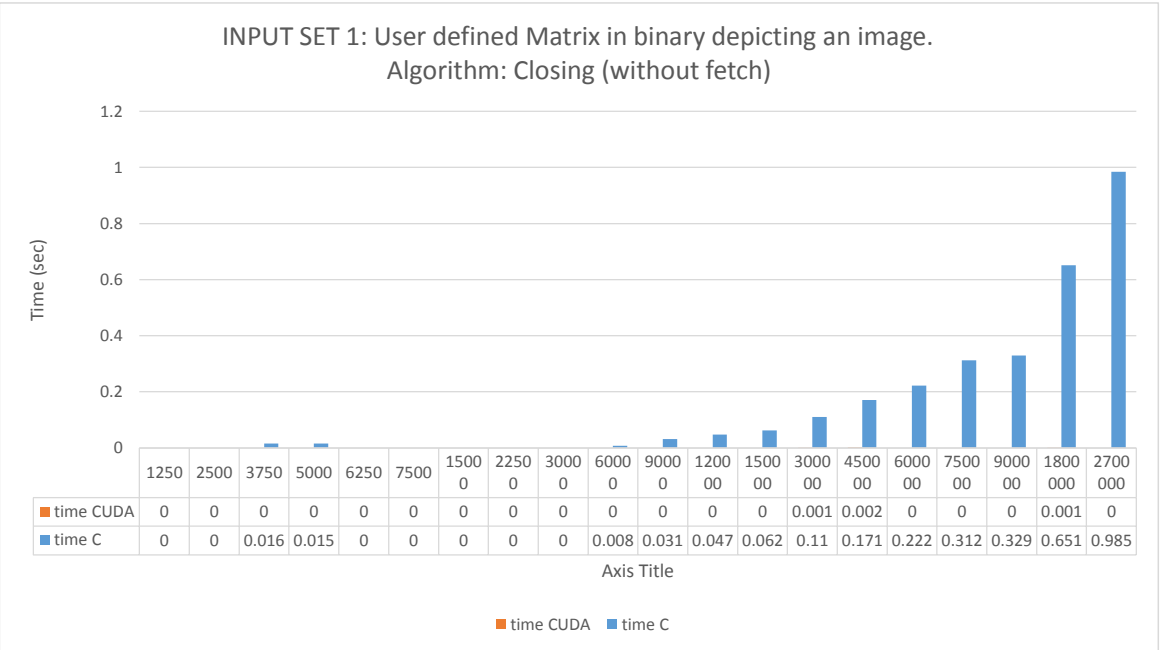

	1250	2500	3750	5000	6250	7500	15000	22500	30000	60000	90000	120000	150000	300000	450000	600000	750000	900000	1800000	2700000
time CUDA	0	0	0	0	0	0	0	0	0	0	0	0	0	0.001	0.002	0	0	0	0.001	0
time C	0	0	0.016	0.015	0	0	0	0	0	0.008	0.031	0.047	0.062	0.11	0.171	0.222	0.312	0.329	0.651	0.985

Overall Observations

Total Time with fetch	Edge	Erosion	Dilation	Opening	Closing	
Standard C++	117.281	115.608	117.588	115.36	118.699	116.9072
CUDA	112.102	91.253	91.071	91.267	90.357	95.21
Standard C++/CUDA (s)	1.046199	1.266895	1.291168	1.263984	1.313667	1.236383
p	0.25	0.338462	0.338462	0.487805	0.487805	0.380507
1-P	0.75	0.661538	0.661538	0.512195	0.512195	**0.619493**
1/(1-P)	1.333333	1.511628	1.511628	1.952381	1.952381	1.65227
P/S	0.23896	0.267158	0.262136	0.385927	0.371331	**0.305102**
1-P+P/S	0.98896	0.928697	0.923674	0.898122	0.883526	**0.924596**
Ahmdal's speedup	1.011163	1.076778	1.082633	1.113435	1.131829	1.083167

Total Time without fetch	Edge	Erosion	Dilation	Opening	Closing	
Standard C++	5.86405	5.7804	5.8794	5.768	5.93495	5.84536
CUDA	5.6051	4.56265	4.55355	4.56335	4.51785	4.7605
Standard C++/CUDA (s)	1.046199	1.266895	1.291168	1.263984	1.313667	1.236383
p	0.25	0.338462	0.338462	0.487805	0.487805	0.380507
1-P	0.75	0.661538	0.661538	0.512195	0.512195	**0.619493**
1/(1-P)	1.333333	1.511628	1.511628	1.952381	1.952381	1.65227
P/S	0.23896	0.267158	0.262136	0.385927	0.371331	**0.305102**
1-P+P/S	0.98896	0.928697	0.923674	0.898122	0.883526	**0.924596**
Ahmdal's speedup	1.011163	1.076778	1.082633	1.113435	1.131829	1.083167

Average Time with fetch	Edge	Erosion	Dilation	Opening	Closing	
Standard C++	0.109	1.608	1.468	2.893	2.959	1.8074
CUDA	0.031	0.034	0.024	0.002	0.004	0.019
Standard C++/CUDA (s)	3.516129	47.29412	61.16667	1446.5	739.75	459.6454
p	0.25	0.338462	0.338462	0.487805	0.487805	0.380507
1-P	0.75	0.661538	0.661538	0.512195	0.512195	**0.619493**
1/(1-P)	1.333333	1.511628	1.511628	1.952381	1.952381	1.65227
P/S	0.071101	0.007157	0.005533	0.000337	0.000659	**0.016958**
1-P+P/S	0.821101	0.668695	0.667072	0.512532	0.512855	**0.636451**
Ahmdal's speedup	1.217877	1.49545	1.499089	1.951096	1.949871	1.622677

Average time without fetch	Edge	Erosion	Dilation	Opening	Closing	
Standard C++	0.00545	0.0804	0.0734	0.14465	0.14795	0.09037
CUDA	0.00155	0.0017	0.0012	0.0001	0.0002	0.00095
Standard C++/CUDA (s)	3.516129	47.29412	61.16667	1446.5	739.75	459.6454
p	0.25	0.338462	0.338462	0.487805	0.487805	0.380507
1-P	0.75	0.661538	0.661538	0.512195	0.512195	**0.619493**
1/(1-P)	1.333333	1.511628	1.511628	1.952381	1.952381	1.65227
P/S	0.071101	0.007157	0.005533	0.000337	0.000659	**0.016958**
1-P+P/S	0.821101	0.668695	0.667072	0.512532	0.512855	**0.636451**
Ahmdal's speedup	1.217877	1.49545	1.499089	1.951096	1.949871	1.622677